



Effect of Meteorological Parameters on the Frequency of Acute Myocardial Infarction Events: A Retrospective Study

Meteorolojik Parametrelerin Akut Miyokard Enfarktüsü Olaylarının Sıklığı Üzerindeki Etkisi: Retrospektif Bir Çalışma

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ABSTRACT

Aim: Environmental factors, diet, exercise, smoking, and psychological and physical stress affect the frequency of acute myocardial infarction (AMI). Weather events also affect this frequency. This study aimed to investigate the effects of meteorological parameters in Amasya/Türkiye on AMI frequency.

Material and Methods: We evaluated the association of the frequency of AMI subtypes, such as unstable angina pectoris (USAP), non-ST-elevation myocardial infarction (NSTEMI), or ST-elevation myocardial infarction (STEMI), with meteorological parameters over 6 years.

Results: AMI frequency significantly increased in the winter. In summer, there was a significant positive relationship between the mean current pressure and the number of NSTEMI events. The STEMI risk was 1,174 times higher in summer than in winter and 1,214 times higher in summer than in spring. Non-ST-elevation myocardial infarction risk was 1,138 times higher in winter than in summer. The USAP risk was 1,350 times higher in winter than in summer. In summer, a significant positive relationship was observed between total precipitation and the number of USAP events. Among meteorological parameters, air temperature was closely associated with AMI risk.

Conclusions: We observed that AMI frequency increases, particularly in the winter, when the average temperature is low. Thus, establishing awareness of avoiding long-term exposure to cold weather can help reduce the risk of low-temperature-related AMI.

Key words: acute myocardial infarction; air temperature; atherosclerosis; cold weather

ÖZET

Amaç: Çevresel faktörler, diyet, egzersiz, sigara içme ve psikolojik ve fiziksel stresin akut miyokard enfarktüsü (AMI) sıklığını etkilediği gibi hava olayları da bu sıklığı etkiler. Bu çalışma, Amasya/Türkiye’de meteorolojik parametrelerin AMI sıklığı üzerindeki etkilerini araştırmayı amaçlamıştır.

Gereç ve Yöntemler: Kararsız angina pectoris (USAP), ST yükselmesiz miyokard enfarktüsü (NSTEMI) veya ST yükselmesiz miyokard enfarktüsü (STEMI) gibi AMI alt tiplerinin sıklığının meteorolojik parametrelerle ilişkisini altı yıllık bir periyotta değerlendirdik.

Bulgular: AMI sıklığı kışın önemli ölçüde arttı. Yaz aylarında, ortalama mevcut basınç ile NSTEMI olaylarının sayısı arasında önemli bir pozitif ilişki vardı. STEMI riski yaz aylarında kışa göre 1.174 kat ve yaz aylarında ilkbahara göre 1.214 kat daha yüksekti. NSTEMI riski kışın yaza göre 1.138 kat daha yüksekti. Kararsız angina pectoris riski kışın yaza göre 1.350 kat daha yüksekti. Yazın, toplam yağış ile USAP olaylarının sayısı arasında anlamlı bir pozitif ilişki gözlemlendi. Meteorolojik parametreler arasında, hava sıcaklığının AMI riski ile yakından ilişkili olduğu görüldü.

Sonuç: Akut miyokard enfarktüsü sıklığının, özellikle ortalama sıcaklığın düşük olduğu kış aylarında arttığını gözlemledik. Bu nedenle, soğuk havaya uzun süreli maruz kalmaktan kaçınma konusunda farkındalık oluşturmak, düşük sıcaklıkla ilişkili AMI riskini azaltmaya yardımcı olabilir.

Anahtar kelimeler: akut miyokard enfarktüsü; hava sıcaklığı; ateroskleroz; soğuk hava

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Introduction

Health is a state of biological, psychological, and social well-being. Human health is affected by many factors, including the environment in which a person lives and weather conditions. Along with the changing seasons, changes in air temperature also have a significant impact on human health. Recent epidemiological studies have shown that chronobiological and environmental factors, such as air temperature, air pollution, relative humidity, precipitation, wind, and atmospheric pressure, affect the frequency of acute myocardial infarction (AMI)^{1,2}. Decreases in temperature during the autumn and winter months significantly affect social life, human psychology, hormonal balance, and many systems in the human body. Blood pressure, glucose level, heart rate, blood fluidity, brain activity, skeletal system mobility, gastrointestinal habits, and skin tension are affected by air temperature³⁻⁶.

The mechanisms related to the effects of meteorological parameters on AMI frequency are multifactorial. As a result of activation of the sympathetic nervous system in cold weather conditions, blood pressure, heart rate, left ventricular end-diastolic pressure, and myocardial oxygen demand increase with catecholamine overflow. Subsequently, the cardiac diastole period shortens, and coronary blood flow begins to deteriorate. The ischemia threshold decreases, and the coagulation cascade is activated⁷⁻¹⁰. Another mechanism is that, in cold weather, constriction occurs in the vascular bed to maintain the body's internal temperature at a certain level, which results in increased blood pressure. Total vasoconstriction increases arterial wall stress; therefore, this phenomenon is an important precursor of coronary plaque rupture and AMI¹¹⁻¹⁴.

Cold weather conditions are associated with pro-inflammatory and prothrombotic activation. Prothrombotic activation is associated with plaque rupture, which can lead to acute coronary syndrome^{15,16}. Cold weather also increases the formation of new platelets, and tendency to clot. Consequently, as the viscosity and number of red blood cells increases, the amount of blood plasma decreases¹⁷⁻¹⁹. In cold weather, there is a relative increase in cholesterol levels owing to hemoconcentration, an increase in average daily calorie intake, and a decrease in physical activity. In addition, the incidence of upper respiratory tract infections increases during cold weather. Influenza is specifically associated with an increased risk of AMI¹⁸⁻²⁰.

To the best of our knowledge, no study has been conducted in Türkiye investigating the effects of weather changes on myocardial infarction. We believe that this is an important public health issue in our country, where dynamic weather changes are observed, and that studies conducted in this area are valuable for primary prevention measures. Therefore, we aimed to reveal the effect of meteorological parameters on the incidence of AMI in a group of patients who underwent invasive coronary angiography and percutaneous coronary intervention.

Material and Methods

Study Population and Definitions

Our department, the only third-level hospital in the province, is a high-intensity unit where primary percutaneous coronary intervention (PCI) is performed throughout the day. Approximately 1,000 patients apply to the emergency department of our hospital daily. Patients with a preliminary diagnosis of AMI were accepted from Amasya City Center, the districts, and the surrounding provinces.

We included 5,234 patients, aged >18 years, who were admitted to Amasya University Medical Faculty Education and Research Hospital with a diagnosis of AMI between 1 January 2018 and 1 January 2024 and underwent emergency coronary angiography. The authors had access to information that could identify individual participants during or after data collection. All the data, which has been used for research purposes, was accessed and collected between 15 June 2024 and 30 August 2024. All patients diagnosed with unstable angina pectoris (USAP), non-ST-elevation myocardial infarction (NSTEMI) or ST-elevation myocardial infarction (STEMI), according to the Fourth Universal Definition of Myocardial Infarction, were included²¹. Clinical evidence of acute myocardial ischemia is accompanied by a rise and/or fall in cardiac troponin levels, with at least one value greater than the 99th percentile of the upper reference limit and at least one of the following: symptoms of myocardial ischemia; new ischemic electrocardiogram changes; pathological Q wave formations; imaging evidence of recent loss of viable myocardium or recent regional wall motion abnormalities consistent with ischemic etiology; and detection of a coronary thrombus by angiography or autopsy²².

Ethics Statement

Due to the retrospective nature of the study, the requirement for obtaining informed consent from patients was waived by Amasya University Rectorate Non-Interventional Clinical Research Ethics Committee. The study was approved by the ethics committee of the Amasya University Rectorate Non-Interventional Clinical Research Ethics Committee (document date and number: 08.03.2024-184593; board decision number: E-76988455-050.04-184593). All experiments were performed in accordance with relevant guidelines and regulations.

The values of meteorological parameters for the relevant period were obtained with official permission from the Amasya Meteorology Directorate of the Republic of Türkiye.

Climate Characteristics

Amasya City is located in northern Türkiye, in the Central Black Sea Region. According to data from the General Directorate of State Meteorology, the climate is generally semi-arid and slightly humid, with mild winters and hot, dry summers. Amasya has a transitional climate between the humid Black Sea Climate and the semiarid and continental Central Anatolian climate. The annual average temperature in Amasya is approximately 13.5°C. The difference between the city's summer and winter temperatures is significant (21.3°C); the highest monthly average temperature is seen in August (23.8°C), and the lowest average temperature is seen in January (2.5°C)²³.

Although the city is affected by cold air currents in winter, it is a settlement where snowfall is low. The temperature does not drop significantly in winter, and the summer temperatures are relatively high. The average duration of monthly sunshine was 5.7 h. The average sunshine duration in Amasya is 9.1 hours in the summer months, with the highest duration in July (9.5 hours).

Meteorological data were obtained from the Amasya Meteorology Directorate of the Republic of Türkiye, the only meteorological unit in the city center of Amasya, and included daily, monthly, and annual data tables covering January 2018 to January 2024. Temperature values (°C), relative humidity (%), precipitation (mm), and atmospheric pressure (hPa) were collected. Seasons were defined as follows: Winter months: December, January and February; Spring

months: March, April and May; Summer months: June, July and August; Autumn months: September, October and November.

Statistical Analysis

Data were analyzed using IBM Statistical Package for Social Sciences (SPSS) version 26.0 (IBM Corp., Armonk, NY, USA). The conformity of the data to a normal distribution was examined using Kolmogorov-Smirnov and Shapiro-Wilk tests. One-way analysis of variance was used to compare parameters that were normally distributed among the groups, and multiple comparisons were made using the Duncan and Tamhane Tests. The Kruskal-Wallis test was used to compare parameters that were not normally distributed according to the groups, and multiple comparisons were made using Dunn's test. To examine the relationship between the parameters, the Pearson correlation coefficient was used for data with a normal distribution, and Spearman's rho correlation coefficient was used for those without a normal distribution. Analysis results are presented as the mean $\pm$ standard deviation and median (minimum–maximum). The significance level was set at $p < 0.050$.

Results

Study Population

Of the 5,234 patients included in the study, 2,932 were diagnosed with non-ST-elevation myocardial infarction (NSTEMI; 56.01%), 1,423 with ST-elevation myocardial infarction (STEMI; 27.19%), and 879 with unstable angina pectoris (USAP; 16.80%).

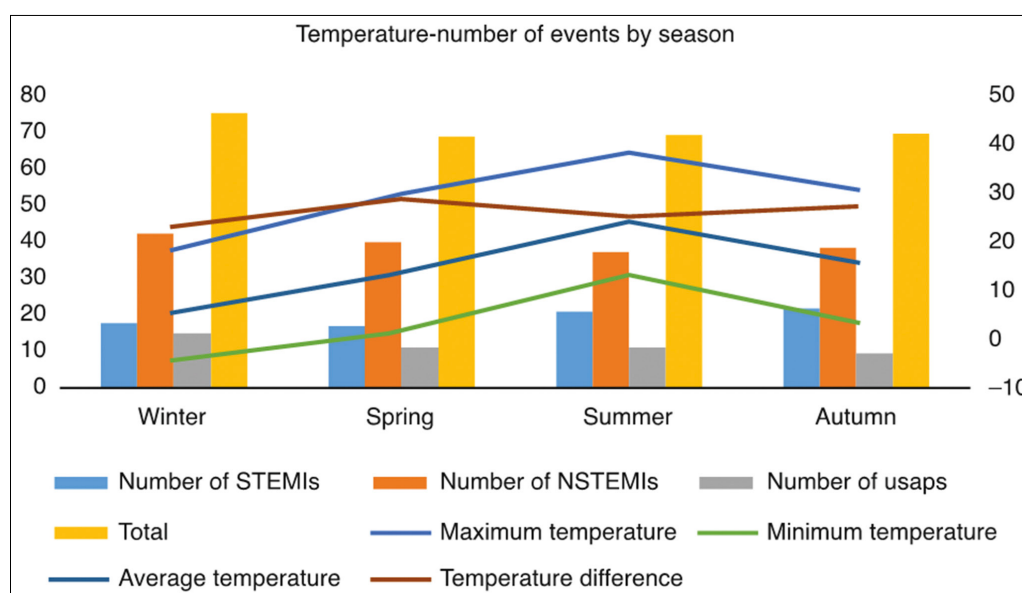
Meteorological Data

Meteorological data were collected from Amasya City and its surroundings, where all patients resided. Between 2018 and 2024, maximum temperatures occurred in summer months, with an average of 38°C, whereas minimum temperatures were observed in winter months, with an average of 15°C. Large temperature variations were observed in the summer months, with an average of 23°C. Relative humidity values were highest in the winter months, averaging 99%. In contrast, the lowest values were recorded at 13% in the summer months. The maximum current pressure was observed in the winter months, averaging 982 hPa, while the average current pressure was also highest in the winter months, averaging 972 hPa. Total precipitation was

Table 1. Number of annual events by season

Year	Winter	Spring	Summer	Autumn
2018	187	135	154	153
2019	280	241	233	233
2020	244	158	141	151
2021	142	211	207	189
2022	168	208	233	260
2023	250	284	276	264
2024	232			
Total number of events	1503	1237	1244	1250
Total number of patients	5234 (STEMI-1423, NSTEMI-2932, USAP-879)			

STEMI: ST-elevation myocardial infarction; NSTEMI: non-ST-elevation myocardial infarction; USAP: unstable angina pectoris.

**Figure 1.** Number of event-temperature relationships by season.

highest in the spring months, averaging 50 mm, which corresponded with the highest number of rainy days, averaging 13 days.

Summer was the hottest season, with the highest rainfall occurring in spring, and the lowest temperatures observed in winter. Relative humidity was highest in winter, whereas the highest atmospheric pressure values were recorded in winter.

Effect of weather conditions on acute coronary syndromes

The total number of seasonal AMI events was 1,503 in winter, 1,237 in spring, 1,244 in summer, and 1,250 in autumn (Table 1). There was a significant increase in the frequency of AMI in winter, when the weather was significantly cold ($p=0.003$). In correlation analyses, a

positive relationship was found between the minimum temperature and number of USAP events in winter ($r=0.542$; $p=0.014$), and a mild-to-moderate relationship ($r=-0.459$; $p=0.042$) between the temperature difference and number of USAP events (Fig. 1).

When the seasons were compared in terms of AMI subtypes (i. e., the summer season values were used as reference values for comparison), the risk of STEMI in summer was 1.174 (1/0.852) times higher than that in winter ($p=0.030$), and 1.214 (1/0.824) times higher than that in spring ($p=0.012$) (Table 2). The risk of NSTEMI in winter was 1.138 times higher than that in summer ($p=0.012$) (Table 2). When the risk of USAP was examined according to season, it was found that the risk in winter was 1.350 times higher than that

Table 2. Analysis of ST-elevation and non-ST-elevation myocardial infarction risk by season

	Season	ERR (95% CI)	p
STEMI	Summer (Reference season)	20,884 (18,878 – 23,104)	<0.001
	Winter	0.852 (0.737 – 0.985)	0.030
	Spring	0.824 (0.71 – 0.958)	0.012
	Autumn	1.013 (0.879 – 1.169)	0.856
NSTEMI	Summer (Reference season)	37,151 (34,467–40,085)	<0.001
	Winter	1.138 (1.028–1.26)	0.012
	Spring	1.078 (0.97–1.197)	0.163
	Autumn	1.035 (0.931–1.15)	0.533

STEMI: ST-elevation myocardial infarction; NSTEMI: non-ST-elevation myocardial infarction; CI: confidence interval; ERR: estimated relative risk. Bold text: statistically significant result.

Table 3. Analysis of unstable angina pectoris and total myocardial infarction risk by season

	Season	ERR (95% CI)	p
USAP	Summer (Reference season)	11,112 (9, 67–12,769)	<0.001
	Winter	1.35 (1.129–1.614)	0.001
	Spring	1.03 (0.848–1.251)	0.766
	Autumn	0.885 (0.723–1.083)	0.236
Total MI	Summer (Reference season)	69.2 (65,431–73,113)	<0.001
	Winter	1.085 (1.007–1.17)	0.032
	Spring	0.994 (0.919–1.075)	0.872
	Autumn	1.004 (0.929–1.085)	0.920

USAP, unstable angina pectoris; MI, myocardial infarction; CI, confidence interval; ERR, estimated relative risk. Bold text: statistically significant result.

in summer ($p=0.001$) (Table 3). When the total risk of myocardial infarction was examined by season, the risk in winter was 1.085 times higher than that in summer ($p=0.032$) (Table 3).

When examining the relationship between the maximum, minimum, and average relative humidity in the winter season and the number of STEMI, NSTEMI, USAP events, and the total number of events, no significant relationship was observed.

There was a significant relationship between the minimum relative humidity and the number of STEMI events ($r=0.538$) ($p=0.021$); however, we observed no significant association of the maximum and average relative humidity in spring with the number of STEMI, NSTEMI, and USAP events and total number of events, or that of the minimum relative humidity with the number of NSTEMI, USAP events, and total number of events.

The relationship between the minimum and average relative humidity in summer and the number of STEMI, NSTEMI, and USAP events, as well as the total number of events, was examined. Similarly, the relationship between the maximum relative humidity

and the number of STEMI and NSTEMI events, as well as the total number of events, was examined, and there were no significant relationships. The relationship between the maximum relative humidity in the summer and the number of USAP events was significant ($r=0.538$) ($p=0.021$).

There was no significant relationship between the maximum, average, and minimum relative humidity in autumn and the number of STEMI, NSTEMI, and USAP events, as well as the total number of events examined (Fig. 2).

When the number of pressure events (measured in hPa) was evaluated according to the seasons, there was no significant relationship between the maximum, minimum, and average current pressures in winter and spring and the number of STEMI, NSTEMI, USAP events, and the total number of events.

In the summer season, there was no significant relationship between the maximum and minimum current pressures and the numbers of STEMI, NSTEMI, and USAP events, or between the mean current pressure and the numbers of STEMI and USAP events. However, there was a significant positive relationship

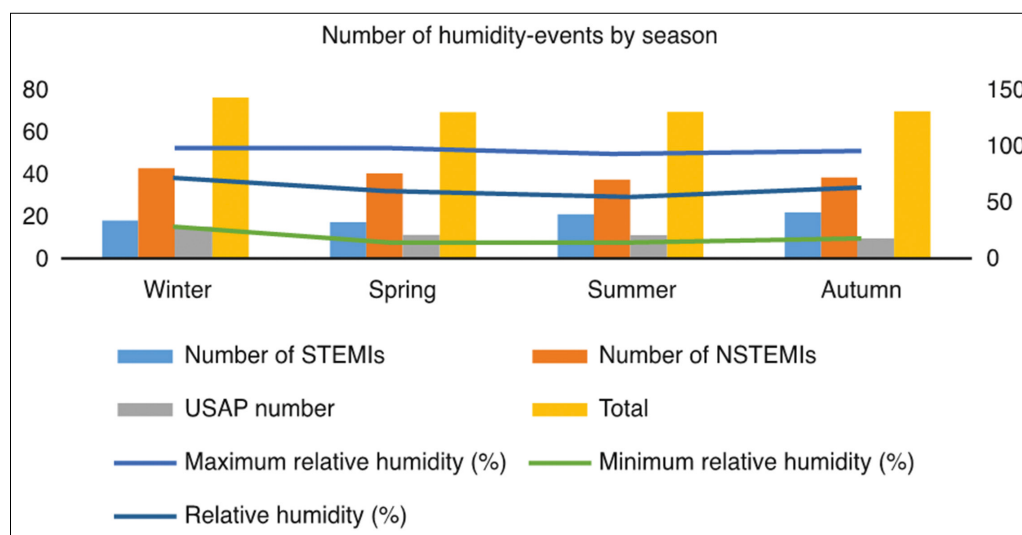


Figure 2. Humidity rate and the number of acute myocardial infarction events by season.

between the mean current pressure and the number of NSTEMI events ($r=0.500$; $p=0.035$).

When the relationship among the maximum, minimum, and mean actual pressures in autumn, as well as the numbers of STEMI, NSTEMI, and USAP events, and the total number of events, was examined, no significant relationship was observed. Also, there was no significant association between total rainfall, the number of rainy days in winter, and the number of STEMI, NSTEMI, USAP, and total myocardial infarctions.

When the relationship between total spring precipitation and the number of STEMI, NSTEMI, and USAP events, as well as the total number of events, and between the number of rainy days and the number of NSTEMI and USAP events, as well as the total number of events, was examined using Spearman correlation, no significant relationship was observed. The relationship between the number of rainy days and the number of STEMI events was significant ($p=0.017$, $r=0.553$).

There was no significant relationship between the total precipitation in summer and the number of STEMI and NSTEMI events, or the total number of events; nor between the number of rainy days and the number of STEMI, NSTEMI, and USAP events, or the total number of events. When the relationship between total precipitation and USAP number was examined using Spearman correlation, there was a significant and moderately positive relationship ($r=0.591$; $p=0.010$).

Discussion

The frequency of AMI was significantly higher in spring and autumn, and it was more pronounced in winter than in summer. When evaluating the effects of meteorological parameters on the frequency of AMI, the minimum and maximum relative humidity, average current pressure, number of rainy days, and total rainfall were associated with the frequency of acute coronary syndrome. The results of our study are consistent with those of previous studies conducted in this field²⁴ and in places with similar seasonal conditions as in our region^{5,25–27}.

Acute myocardial infarction is the main cause of mortality in ischemic heart disease. Acute myocardial infarction is an umbrella term that includes the diagnoses of USAP, NSTEMI, and STEMI. Epidemiological studies have shown that changes in air temperature (especially in cold weather) and certain meteorological parameters (such as relative humidity, the number of rainy/snowy days, atmospheric pressure, and maximum wind direction/speed) increase the risks of acute cardiovascular events and the associated mortality. Simultaneously, some studies have shown that extremely high and low air temperatures increase hospital admissions and AMI mortality^{16,28–30}. In a study conducted in Innsbruck (Austria) comparing two winter seasons with a temperature difference of 7.5°C in two different years, a significant decrease was observed in the number of patients with acute coronary syndrome who underwent emergency coronary angiography during the warm winter period⁶.

Given the severity of global warming, extreme changes in air temperature and climate instability are likely to become more intense and severe in the future³¹. The relationship between low air temperature and AMI is well-defined and is still being investigated. The mortality rate of cardiovascular events was found to be higher in cold weather, and the ratio of fatal to nonfatal cardiovascular events was higher than that in warm periods^{6,32}. A study conducted in Lithuania, examining the associations between cold winter weather and AMI risk, found that each additional cold spell day in the week before AMI increased the risk of AMI by 5%³³.

Until recently, studies investigating the relationship between air temperature and AMI have been mostly conducted in developed countries¹⁰. The lack of access to long-term health data in underdeveloped and developing countries has prevented large-scale studies. In our country, the recent transition to an electronic health record system has made it possible to access reliable data. To date, no large-scale studies have investigated the relationship between weather conditions and coronary events in Türkiye. Similar to other studies in this field³⁴, we observed a decrease in the frequency of AMI, especially in the summer months, and an increase during periods of cold weather, when the perceived temperature decreased. We observed that the frequency of AMI increased on colder days when adaptation to the cold was more difficult.

Studies have shown that the effects of air temperature on AMI are delayed and U- or V-shaped^{35,36}. In our study, the frequency of AMI increased with a decrease in temperature in October, remained high throughout winter, and decreased from May, when temperatures started to rise again. The relative increase in the frequency of AMI in April and May appears to be due to insufficient vascular adaptation when exposed to a sudden temperature increase for 6 hours, as determined by some authors in their studies³⁷. However, we did not use the data from such a short period of time in our study.

Some large-scale studies have also shown a negative effect of relative humidity levels on heart disease³⁸. In our study, we also found that changes in relative humidity values affected the frequency of AMIs. Especially in spring, the relationship between the minimum relative humidity and the number of STEMI events was statistically significant. In summer, the relationship between the maximum relative humidity and the number of USAP events was found to be significant. Previous

studies indicated that relative humidity has no effect on coronary events, or that it can affect the frequency of AMI by affecting the central body temperature and *in vivo* water balance³⁹. In addition, an increase in relative humidity leads to a rise in the amount of water-soluble air particles, and a higher concentration of fine particulate matter increases the frequency of AMI⁴⁰.

According to our research, atmospheric pressure is another meteorological parameter that affects the frequency of AMI. When the relationship between the average current pressure and the number of NSTEMI events in the summer season was examined, a significant and moderately positive relationship was observed. Important studies have been conducted on the effects of atmospheric pressure on the frequency of AMI^{41,42}.

When we examined the effect of the number of rainy days and total precipitation on AMI, we found a significant relationship between the number of rainy days in the spring and the number of STEMI events. There was also a significant positive relationship between total precipitation and the number of USAP events in summer. Although some previous studies found a relationship among the amount of rainfall, number of rainy days, and frequency of AMI^{43,44}, this relationship was not observed in other studies⁴⁵.

A limitation of our study is that we evaluated patients during a certain period of weather and climatic effects (January 2018 – January 2024). In addition, we investigated the effects of meteorological parameters on the frequency of AMI on a monthly and annual scale. Revealing the effects of weekly, daily, and hourly parameter changes on the frequency of AMI could have provided more quantitative data³⁸. Another limitation is that we did not have data regarding the level of exposure to cold weather (outdoor activity and endogenous-exogenous factors) in patients presenting with AMI. If the coronary angiography results of patients could be evaluated on a patient-by-patient basis, incorporating current diagnoses such as myocardial infarction with non-obstructive coronary arteries, it could have provided new insights into identifying other possible mechanisms of AMI-meteorological parameter interactions that have not been defined. Ischemia without obstruction of the coronary arteries appears to be caused by processes acting alone or in combination⁴⁶. We excluded patients who died outside the hospital or before angiography because of AMI. This may have

created a bias in evaluating possible meteorological parameters that have serious and fatal effects.

Another limitation is that we did not evaluate the effect of air pollution on the frequency of AMI. Air pollution, which increases periodically, especially during cold weather, is also associated with an increase in AMI frequency⁴⁷. In addition, these results obtained in Amasya can only be generalized to countries with similar climatic characteristics and socioeconomic environments.

Conclusion

Among the meteorological parameters investigated in this study, air temperature was closely associated with the risk of AMI. The frequency of AMI increases, particularly in the winter months when the average temperature is low. Raising awareness about avoiding long-term exposure to cold weather would be extremely beneficial in reducing the risk of low-temperature-related AMI. It should also be emphasized that before attributing symptoms that may be related to heart disease (such as chest and arm pain, shortness of breath) to seasonal air temperature changes, it is important to seek medical attention and rule out cardiac disease. During periods when cardiovascular risk increases, patients should be thoroughly informed that they must follow the prescribed and protective recommendations to avoid a possible recurrence of the disease after acute treatment. Additional studies are needed to increase awareness in this area, reveal currently unknown pathophysiological mechanisms, and demonstrate the effects of meteorological parameters on AMI at daily and hourly periods.

Author Contributions

A. C. initiated and directed the study, and A. C. and O. K. were the principal investigators. A. C. and O. K. developed the study protocol. A. C. and O. K. collected data. A. C. and O. K. supervised the analysis of data and the writing of the manuscript. A. C. and O. K. performed statistical analyses. A. C. and O. K. drafted the manuscript. All authors read, contributed, and approved the final version of the manuscript.

Ethics Statement

The study was approved by the ethics committee of the Amasya University Rectorate Non-Interventional Clinical Research Ethics Committee (document date

and number: 08.03.2024-184593; board decision number: E-76988455-050.04-184593). All experiments were performed in accordance with relevant guidelines and regulations.

Due to the retrospective nature of the study, the requirement for obtaining informed consent from patients was waived by Amasya University Rectorate Non-Interventional Clinical Research Ethics Committee.

Data Availability Statement

Data is provided within the manuscript or supplementary information files. If needed, the datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

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Conflict of Interest

The authors declare that they have no conflict of interest.

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